

U.S. FISH AND WILDLIFE SERVICE
SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

SCIENTIFIC NAME: *Strymon acis bartrami*

COMMON NAME: Bartram's hairstreak butterfly

LEAD REGION: 4

INFORMATION CURRENT AS OF: May 2010

STATUS/ACTION

☐ Species assessment - determined we do not have sufficient information on file to support a proposal to list the species and, therefore, it was not elevated to Candidate status

☐ New candidate

☒ Continuing candidate

☒ Non-petitioned

☐ Petitioned - Date petition received:

☐ 90-day positive - FR date:

☐ 12-month warranted but precluded - FR date:

☐ Did the petition request a reclassification of a listed species?

☐ Listing priority change

Former LP: ☐

New LP: ☐

Date when the species first became a Candidate (as currently defined): September 12, 2006

☐ Candidate removal: Former LPN: ☐

☐ A – Taxon is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.

☐ U – Taxon not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species.

☐ F – Range is no longer a U.S. territory.

☐ I – Insufficient information exists on biological vulnerability and threats to support listing.

☐ M – Taxon mistakenly included in past notice of review.

☐ N – Taxon does not meet the Act's definition of "species."

☒ X – Taxon believed to be extinct.

ANIMAL/PLANT GROUP AND FAMILY: Insects, Lycaenidae

HISTORICAL STATES/TERRITORIES/COUNTRIES OF OCCURRENCE: Florida, U.S.

CURRENT STATES/COUNTIES/TERRITORIES/COUNTRIES OF OCCURRENCE: Florida, Monroe and Miami-Dade Counties, U.S.

LAND OWNERSHIP: The mainland population is within Long Pine Key in Everglades National Park (ENP). Total acreage including land and water of ENP in Miami-Dade, Monroe, and Collier Counties is 610,684 hectares (ha) [1,509,000 acres (ac)]. In addition, sporadic and localized occurrences of Bartram's hairstreak (*Strymon acis bartrami*) have been found within pine rockland fragments on lands owned by Miami-Dade County. Relict pine rocklands on other private lands may also provide suitable or potential habitat. In the Florida Keys, the butterfly occurs on Big Pine Key within National Key Deer Refuge (NKDR) and on private, State, and other lands (Salvato and Hennessey 2004, p. 223; M. Salvato, Service, pers. comm. 2009). The NKDR is 3,723 ha (9,200 ac).

LEAD REGION CONTACT: Erin Rivenbark, 404-679-7379, erin_rivenbark@fws.gov

LEAD FIELD OFFICE CONTACT: South Florida Ecological Services Office, Paula Halupa, 772-562-3909 ext 257, paula_halupa@fws.gov

BIOLOGICAL INFORMATION

Species Description: The Bartram's hairstreak is a small butterfly approximately 25 millimeters (mm) (1 inch (in)) in length with a forewing length of 10 to 12.5 mm (0.4 to 0.5 in) and has an appearance (i.e., color, size, body shape) characteristic of the genus (Pyle 1981, p. 480; Opler and Krizek 1984, p. 107-108; Minno and Emmel 1993, p. 129). Despite its rapid flight, this hairstreak is easily observed if present at any density as it alights often, and the brilliance of its grey underside marked with bold white postdiscal lines beneath both wings provides an instant flash of color against the foliage of its host plant, pineland croton (*Croton linearis*) (Euphorbiaceae) (Smith *et al.* 1994, p. 118; Salvato 1999, p. 124). The Bartram's hairstreak does not exhibit sexual or seasonal dimorphism, but does show some sexual differences. The abdomen of the male is bright white, while females are gray (M. Minno, Eco-Cognizant, Inc., pers. comm. 2009).

Eggs are laid singly on the flowering racemes of pineland croton (Worth *et al.*, 1996, p. 62; Salvato and Hennessey 2004, p. 225). First and second instars remain well camouflaged amongst the white croton flowers, while the greenish later stages occur more on the leaves. Salvato and Hennessey (2004, p. 225) reported approximate body lengths 2, 4, 6, and 11 mm for Bartram's hairstreak 2nd through 5th instar larvae, respectively.

Taxonomy: The Bartram's hairstreak butterfly, *Strymon acis bartrami*, was first described by Comstock and Huntington in 1943. Seven subspecies of *Strymon acis* have been described (Smith *et al.* 1994, p. 118). Smith *et al.* (1994, p. 118) indicated that perhaps no other butterfly in the West Indies has evolved as many distinct island subspecies as *S. acis*. Each group of Antillean islands appears to have its own particular set of *S. acis* hairstreaks, and these have been classified into two separate groups. The Type A subspecies are larger, darker colored and are

found in the more southeastern Antillean islands. The Type B subspecies, to which the Bartram's hairstreak belongs, are smaller, more surface-grey colored. Bartram's hairstreak is endemic to Florida and occurs nowhere else in the world.

The Integrated Taxonomic Information System (2010, p. 1) uses the name *Strymon acis bartrami* and indicates that this species' taxonomic standing is valid. The Florida Natural Areas Inventory (FNAI) (2010, p. 20) and NatureServe (2009, p. 1) use the name *S. a. bartrami*.

We have carefully reviewed the available taxonomic information on the Bartram's hairstreak (Smith *et al.* 1994, p. 118; Worth *et al.* 1996, p. 62; Salvato and Hennessey 2004, p. 223; Pelham 2008, p. 231) and have reached the conclusion that *S. acis bartrami* is a valid taxon and an entity that could be listed pursuant to the Endangered Species Act.

Habitat/Life History: Pineland croton, a subtropical species of Antillean origin, is the only known host plant for Bartram's hairstreak (Opler and Krizek 1984, p. 108; Schwartz 1987, p. 16; Minno and Emmel 1993, p. 129; Smith *et al.* 1994, p. 118). Once occurring throughout the pine rocklands of the lower Florida Keys (Dickson 1955, p. 98; Hennessey and Habeck 1991, p. 13; Salvato 1999, p. 3), pineland croton now occurs only on Big Pine Key. The last reports of the host plant from other keys were from No Name in 1992 (Carlson *et al.* 1993, p. 923) and from Little Pine (Hennessey and Habeck 1991, p. 4). Recent surveys of relict pineland throughout the lower Keys by Salvato (1999, pers. comm. 2008) failed to locate the plant from any island other than Big Pine. Hennessey and Habeck (1991, p. 4) and Salvato (1999, p. 3) estimated that approximately 80 ha (198 ac) of croton-bearing pine rockland habitat occur on Big Pine Key. More recently, Chad Anderson (pers. comm. 2010a), biologist at NKDR, estimated roughly 243 ha (600 ac) of croton on Big Pine Key, based upon Bradley's pine rockland data and personal observations.

Another 1,068 ha (2,639 ac) of pine rockland habitat with pineland croton occur within ENP (Hennessey and Habeck 1991, p. 4; Salvato 1999, p. 3). ENP staff and volunteers are mapping croton throughout Long Pine Key, but more information on its distribution is needed (J. Sadle, pers. comm. 2007, 2010a; S. Perry, pers. comm. 2007).

A GIS analysis for Miami-Dade County indicated that 65 pine rockland fragments containing croton remain in private ownership, totaling approximately 190 ha (470 ac) (The Institute for Regional Conservation [IRC] 2006).

In pine rockland habitat, frequent fires burn back the overgrowth of the herbaceous layer. Most shrubs, including pineland croton, re-sprout after fire. Re-sprouting after burns is the primary mechanism allowing for the persistence of perennial shrubs in pine habitat (Olson and Pratt 1995, p. 101). On Big Pine Key, Anderson (pers. comm. 2010a) found new seed germination (n=102 in approximately 10 ac) after fire and noted the ratio of seedling germination to resprouts was more than 2:1 (102:43, n=261) in the crotons surveyed in his study. Without fire, tropical pineland changes to hardwood hammock as broad-leaved trees and shrubs shade out the pineland plants. The conversion of pine rockland into hardwood hammock is continuing on northeastern Big Pine, No Name, Cudjoe, Sugarloaf, and Little Pine Keys; pineland croton is now largely

absent from these locations. Minno (pers. comm. 2009) indicates that the butterfly prefers areas with trees and patches of the host plant rather than large open areas. Anderson (pers. comm. 2010a) notes that the area of highest concentration of Bartram's hairstreak on Big Pine Key in 2009 occurred in an open area that does not have trees.

This species is rarely encountered more than 5 meters (m) (16.4 feet) from its host plant (Schwartz 1987, p. 16; Worth *et al.* 1996, p. 65, Salvato and Salvato 2008, p. 324). Salvato (pers. comm. 2010) believes that a fire-return interval of 3 to 5 years may be most conducive for maintaining Bartram's hairstreak on the mainland; less frequent fire is needed in the Keys. Since the butterfly cannot disperse very far, it is likely important to have patches of croton and nectar sources in close proximity to one another. Ideal habitat may be nearly uniform / evenly distributed croton interspersed with nectar sources and trees.

Females oviposit on the flowering racemes of pineland croton (Worth *et al.*, 1996, p. 62; Salvato and Hennessey 2004, p. 225). Eggs are laid singly on the developing flowers. Hennessey and Habeck (1991, p. 18) observed a female oviposit three eggs over the course of five minutes. This long duration likely enables females to serve as one of the major pollinating species for the host plant (Salvato 2003, p. 57).

The Bartram's hairstreak is most often observed visiting pineland croton flowers for nectar, but has also been observed using the flowers of other species, including: pine acacia (*Acacia pinetorum*), Spanish needles (*Bidens alba*), saw palmetto (*Serenoa repens*), buttonsage (*Lantana involucrata*), Bloggett's swallowwort (*Cynanchum blodgettii*), Everglades Key false buttonwood (*Spermacoce terminalis*), and starrush whitetop (*Rhynchospora colorata*) (Minno and Emmel 1993, p. 129; Worth *et al.* 1996, p. 65; Calhoun *et al.* 2002, p. 14; Salvato and Hennessey 2004, p. 226; Salvato and Salvato 2008, p. 324). Recently, Anderson (pers. comm. 2010a) documented the butterfly nectaring on locustberry (*Byrsonima lucida*).

The Bartram's hairstreak has been observed during every month on Big Pine Key and ENP; however the exact number of broods appears to be sporadic from year to year (Salvato and Hennessey 2004, p. 226). Baggett (1982, p. 81) indicated that the Bartram's hairstreak seemed most abundant in October-December. Salvato (1999, p. 47) recorded 92 adult Bartram's hairstreak on Big Pine Key during a one-week period in July 1997, suggesting the species can occur in high numbers throughout the year if suitable habitat and conditions are present (M. Salvato, pers. comm. 2006).

Historical Range/Distribution: Bartram's hairstreak is endemic to south Florida and the lower Keys. The species was locally common within the pine rockland habitat that occurred in Miami-Dade and Monroe Counties, and less common and more sporadic within croton-bearing pinelands in Collier, Palm Beach, and Broward Counties (Baggett 1982, p. 81; Smith *et al.* 1994, p. 118; Salvato and Hennessey 2004, p. 223). However, development has removed and/or fragmented pine rocklands from the majority of the hairstreak's former range (Salvato and Hennessey 2004, p. 223; Salvato and Salvato 2008, p. 323, Salvato and Salvato, in press). This rapid loss of habitat and the resulting increased distance between substantial populations of host plants in the remaining pine rocklands is the most likely cause for the disappearance of the

hairstreak from most of its historic range.

Current Range/Distribution: Populations of Bartram's hairstreak have become increasingly localized as pine rockland habitat has been lost or altered through anthropogenic activity (Baggett 1982, p. 81; Hennessey and Habeck 1991, p. 4; Schwarz *et al.* 1996, p. 59; Salvato and Hennessey 2004, p. 223). Long Pine Key contains the largest remaining coverage of pine rockland habitat (8,029 ha) (19,840 ac) on the mainland (Table 1) (Salvato 1999, p. 3; Service 1999, p. 173; Salvato and Hennessey 2004, p. 223). However, Hennessey and Habeck (1991, p. 4) and Salvato (1999, p. 3) estimated that approximately 1,068 ha (2,638 ac) of appropriate host plant-bearing pine rockland habitat (Table 1) occur within Long Pine Key. This appears to be the best estimate at this time. More information on the distribution of croton within Long Pine Key is needed (J. Sadle, pers. comm. 2007, 2010b; S. Perry, pers. comm. 2007).

In Miami-Dade County, outside of ENP, there are approximately 375 pine rockland fragments remaining totaling approximately 1,780 ha (4,398 ac; Table 1) (Service 1999, p. 173). Several of these fragments, particularly those adjacent to ENP, such as Navy Wells Pineland Preserve (Navy Wells) and Camp Owaissa Bauer Hammock, appear to maintain small, localized populations of pineland croton as well as sporadic occurrences of Bartram's hairstreak (Salvato 1999, p. 123; Salvato and Hennessey 2004, p. 223; M. Salvato, pers. comm. 2009). A GIS analysis conducted by the Service using data collected by IRC in 2004 indicated that 65 pine rockland fragments containing pineland croton remain in private ownership in Miami-Dade County totaling approximately 190 ha (470 ac; Table 1) (IRC 2006). Another 12 fragments totaling 180 ha (446 ac; Table 1) contain croton and are in public ownership (IRC 2006).

In the lower Keys, Big Pine Key retains the largest undisturbed tracts of pine rockland habitat totaling an estimated 701 ha (1,732 ac; Table 1) (Folk 1991, p. 218; Hennessey and Habeck 1991, p. 4; Salvato and Hennessey 2004, p. 223). Minno (pers. comm. 2009) notes that the 2004 land cover data from South Florida Water Management District maps 516 ha (1,276 ac) of pine rockland on Big Pine Key. Although relict pine rocklands can still be found on several other islands within NKDR, only Big Pine Key maintains pineland croton (Salvato 1999, p. 4; Salvato and Hennessey 2003, p. 243; 2004, p. 223). As a result, the Bartram's hairstreak is present only on Big Pine Key. Hennessey and Habeck (1991, p. 4) and Salvato (1999, p. 3) estimated that approximately 80 ha (198 ac; Table 1) of croton-bearing pine rockland occur on Big Pine Key. More recently, Anderson (pers. comm. 2010a) suggested an estimate of 243 ha (600 ac) of croton on Big Pine Key.

Table 1: Estimated area of pineland rockland habitat and pineland croton-bearing habitat.

Site	Pine rockland habitat hectares (acres)	Pineland croton-bearing habitat hectares (acres)
Long Pine Key	8,029 (19,840)	1,068 (2,638)
Big Pine Key	701 (1,732)	80 (198) – 243 (600)
Miami-Dade County	1,780 (4,398)	190 (470) – private ownership
		180 (446) – public ownership
Total	10,510 (25,970)	1,518 (3,752) – 1,761 (4,352)

Population Estimates/Status: Based on the results of historic (Baggett 1982, p. 80; Schwartz 1987, p. 16; Hennessey and Habeck 1991, p. 117-119; Worth *et al.* 1996, p. 62-65; Schwarz *et al.* 1996, p. 59-61) and recent (Salvato 1999, p. 1; 2001, p. 8; 2003, p. 53; Salvato and Hennessey 2004, p. 223; M. Salvato, pers. comm. 2009) surveys and natural history studies, the Bartram's hairstreak is extant in ENP and on Big Pine Key, while sporadically occurring in pineland fragments in mainland Miami-Dade County. Hennessey and Habeck (1991, p. 49-50) reported an estimate of 3.9 and 1 adult Bartram's hairstreaks per ha (1.6 and 0.4 per ac) during 1988-1989 survey transects on Big Pine Key and Long Pine Key, respectively. During 1997-1998, Salvato (1999, p. 52) recorded an estimated 4.3 adults per ha (1.7 per ac) at survey transects across Big Pine Key. However, Salvato (1999, p. 52; 2001, p. 8) failed to find stable numbers in either the Watson's Hammock on Big Pine Key or in Long Pine Key. The lower densities in Watson's Hammock and Long Pine Key reported by Salvato (1999, p. 52; 2001, p. 8-14; pers. comm. 2006) and Salvato and Hennessey (2004, p. 224) during the late 1980s and 1990s have been attributed to a lack of prescribed fires necessary to maintain host plants. Through 2007, Salvato (pers. comm. 2008) recorded an average of 2.9 to 10.3 adults per ha (1.2 to 4.2 per ac) at transects across Big Pine Key from 1999-2007. In March 2009, a high concentration of the butterfly and its host plant was recorded at one area of NKDR (C. Anderson, pers. comm. 2009). However, as of April 28, 2010, Anderson (pers. comm. 2010b) had only observed 2 adults on NKDR in 2010.

Salvato (1999, p. 122; 2003, p. 57) noted that the Bartram's hairstreak had either been extirpated or greatly reduced across the majority of Long Pine Key at the time of his 1997-1998 studies. However, due in large part to an effective and systematic burn plan, Salvato and Salvato (in press) have encountered as many as 15 adult Bartram's hairstreak annually at Gate 4 from 1999-2008. In addition, Salvato and Salvato (in press) has also monitored populations of the Bartram's hairstreak at other gates within Long Pine Key during 2005-2008 and encountered similar densities. Overall, Perry (pers. comm. 2007) has observed only small, scattered occurrences within the spatially extensive pineland area of Long Pine Key. She notes that counts are typically only in the single digits during her survey efforts.

Salvato (pers. comm. 2009) estimated that the population collectively at Big Pine Key, Long Pine Key, and within relict pine rocklands adjacent to ENP ranges from several hundred or fewer, although it varies greatly depending upon season and other factors. Despite extensive monitoring, Salvato (pers. comm. 2009) only sporadically observes the species within pine rockland areas adjacent to ENP, such as Navy Wells. However, one such pine rockland fragment, Navy Wells, continues to maintain a consistent population of Bartram's hairstreak (Salvato and Salvato, in press).

Minno (pers. comm. 2007, 2009) and Minno and Minno (2009, p. 70-76) reported that Bartram's hairstreak occurs on Big Pine Key, at Navy Wells, Larry and Penny Thompson Memorial Park, MetroZoo Preserve, and in ENP; however, it is not common. Sites such as Navy Wells and Camp Owaissa Bauer Hammock appear to maintain small, localized populations of pineland croton and sporadic occurrences of Bartram's hairstreak (Salvato 1999, p. 123; Salvato and Hennessey 2004, p. 223; M. Salvato, pers. comm. 2009). Minno (pers. comm. 2007) reports observing <10 individuals after a day of sampling on Big Pine, which is "extremely low

population numbers for a butterfly.” Minno (pers. comm. 2007) indicated that the butterfly is present at Navy Wells, but that many plants at this site were killed by frost in the spring of 2007, including croton. However, the butterfly survived at this site (M. Minno, pers. comm. 2009). Similarly, Minno (pers. comm. 2007) found one individual in ENP shortly after the freeze. Sadle (pers. comm. 2010a) also noted that Navy Wells sustained frost damage, then was partially burned in January 2010. During 2008 through 2010, Salvato (pers. comm. 2010) has frequently encountered adults at Navy Wells, including a high of 12 individuals on May 22, 2010. In addition, croton appears to have responded well to prescribed burns conducted throughout the preserve, with fresh croton growth occurring in many locations (Salvato pers. comm. 2010).

Minno (pers. comm. 2007) believes that this species has declined greatly since the 1980s and is not likely to survive without special efforts. Bartram’s hairstreak may be at least as rare as the federally endangered Schaus swallowtail (*Heraclides aristodemus ponceanus*) (M. Minno, pers. comm. 2009). Minno (pers. comm. 2009) indicated that the current population size is not known, but thought to be declining; he believes it is likely to be less than 100 per day for all locations combined. Minno and Minno (2009, p. 76) recorded 143 adults on Big Pine Key, 36 adults in Miami-Dade County preserves, and 14 adults in ENP during surveys conducted in the Keys and southern Florida mainland from August 2006 through June 2009.

The Bartram’s hairstreak has a rounded global status of T1, critically imperiled because of extreme rarity (i.e., 5 or fewer occurrences of less than 1,000 individuals) or because of extreme vulnerability to extinction due to natural or manmade factors (NatureServe 2009, p. 1). The basis for this ranking stems from the overall threats of range being reduced by development, pesticide application, fire (prescribed or otherwise), complete fire suppression, and hurricanes as well as restricted distribution, low abundance, and loss of habitat (NatureServe 2009, p. 1-2). This butterfly is recognized in Florida’s Comprehensive Wildlife Conservation Strategy as one of Florida’s species of greatest conservation need, with status low and trend unknown (Florida Fish and Wildlife Conservation Commission [FWC] 2005, p. 91). Bartram’s hairstreak is not listed in Florida, and there is no wildlife management plan for this species.

THREATS

- A. The present or threatened destruction, modification, or curtailment of its habitat or range.
The pine rockland community of southern Florida is globally endangered. Destruction of the pinelands for economic development has reduced this community by 90 percent on mainland south Florida (O’Brien 1998, p. 208). Similarly, most of the ecosystems on the Keys have been impacted by humans, through widespread clearing of habitat in the 19th century for farming, or building of homes and businesses; extensive areas of pine rocklands have been lost (Hodges and Bradley 2006, p. 6). Suitable habitat for this butterfly on unprotected pine rocklands outside of ENP and NKDR largely remains at risk to development, fire suppression, and lack of fire management. Plans are underway to develop public lands adjacent to the Miami Metro Zoo for a water park (J. Maguire, pers. comm. 2010). However, Miami-Dade County has indicated it will construct the proposed water park in areas with existing concrete or areas otherwise not occupied by listed or candidate species (J. Maguire, pers. comm. 2010). Therefore, this development is not likely to curtail

management of adjacent pine rocklands or cause habitat modification of areas which currently support sporadic occurrences of Bartram's hairstreak (M. Salvato, pers. comm. 2010).

The threat of habitat destruction or modification is further exacerbated by lack of prescribed fire and suppression of natural fires, which are an important part of maintaining an ecosystem's gradual succession and are important in maintaining the herbaceous layer of pine rocklands of which pineland croton is a part (Loope and Dunevitz 1981, p. 5; Carlson *et al.* 1993, p. 914; Olson and Platt 1995, p. 101; Bergh and Wisby 1996, p. 1). Due to the proximity of remaining pine rockland habitat to urban areas, much of these natural fires (outside of ENP) have been suppressed, often replaced by inconsistent regimes of managed or prescribed fires.

Prescribed fire is used throughout the pine rocklands of Long Pine Key and has been consistently used for the past 50 years (Loope and Dunevitz 1981, p. 5; Salvato 1999, p. 8). Little is known about the fire history in ENP prior to 1947, and at first, fires were suppressed (Slocum *et al.* 2003, p. 93). Fires were reintroduced in the late 1950s, but were not well understood (Slocum *et al.* 2003, p. 93). However, many of the prescribed burns conducted in Long Pine Key during this time period were quite extensive, with several areas (now known as burn blocks) treated simultaneously. Beginning in 1989, efforts were made to generate more natural fire regimes by focusing on increasing frequency and shifting the timing of burn from the nonlightning (winter) to lightning (summer) seasons (Slocum *et al.* 2003, p. 93). In 1989 and 1990, all of Long Pine Key was prescribed burned during the early to middle lightning season to initiate a restoration effort based on the hypothesized natural fire regime (i.e., increased frequencies and correct timing) (Slocum *et al.* 2003, p. 93). Since that time, fires have been ignited every 2 to 3 years, with most ignitions occurring in the early to middle lightning season (Slocum *et al.* 2003, p. 93). Although this has resulted in restoration of species-rich, herbaceous-dominated pine rocklands in many areas, including resurgence of croton, populations of croton appear fragmented (Salvato and Hennessey 2004, p. 223-227). Because this species is rarely encountered more than 5 meters (m) (16.4 feet) from its host plant (Schwartz 1987, p. 16; Worth *et al.* 1996, p. 65, Salvato and Salvato 2008, p. 324), it is believed that the historic large prescribed fires (i.e., involving multiple burn units) of Long Pine Key may have eradicated hairstreaks at the burn sites (Salvato 1999, p. 122). The desired fire return interval for prescribed fires in Long Pine Key is considered to be 2 to 5 years (A. Land, pers. comm. 2010). However, immature stages are destroyed by fire (M. Minno, pers. comm. 2009) (see Threats, Factor E below).

Since 2001, prescribed fire within Long Pine Key has been planned on a landscape scale versus unit scale (National Park Service [NPS] 2005, p. 27) using partial and systematic prescribed burns conducted in a way that burns nearly all of the pine rocklands over a three-year window. However, no one knows if this will have a positive or negative effect on the butterfly (M. Minno, pers. comm. 2009). This method attempts to burn adjacent pine rockland habitats alternately. This practice could allow a corridor to refugia for the butterflies to traverse at the time of the burn in which they can remain while the burned site regenerates. Bartram's hairstreaks may then be provided an easier route back to the recently

burned adjacent area, which could aid in faster re-colonization.

Ideally, during this three-year interval, the butterflies will move from the burned location to adjacent refugia and then back to burned area in numbers equal to or greater than before the fire. The effects of this new burn technique were not immediately obvious when this plan took effect, but starting in the fall of 2004 and continuing into early 2006, the hairstreak appeared to have benefited with population densities greater than those recorded in any of the previous studies (M. Salvato, pers. comm. 2007). However, at one point, low numbers of butterflies in the pinelands were partially attributed to burning too soon following hurricanes and flooding and before host plants were fully recovered, as well as other factors (S. Perry, pers. comm. 2007). In May 2005, select portions of Long Pine Key were prescribed burned, but resurgence of vegetation within these burned areas was set back due to storm damage caused by Hurricanes Katrina and Wilma later that year (M. Salvato, pers. comm. 2007). By mid-2006, croton within these areas had not recovered, yet burns adjacent to these areas continued, removing available host plants (M. Salvato, pers. comm. 2007). ENP did not, however, detect any strong changes in croton height or crown area following the hurricanes within study plots used as part of its croton monitoring study (A. Land, pers. comm. 2008). In general, Salvato (pers. comm. 2010) believes that a fire-return interval of 3 to 5 years may be most conducive for maintaining Bartram's habitat on the mainland; less frequent fire is needed in the Keys. Although management in ENP in recent years has apparently benefited the Bartram's hairstreak, adaptive management needs to be implemented during instances where recovery of recently burned areas is slowed (Salvato and Salvato, in press).

The objectives of the current NKDR fire management program are to: (1) protect human life, property, and other resources from unwanted fire and (2) restore and maintain biological diversity using fire as a viable ecological process (Service 2000, p. 1). The latter includes maintaining biological diversity in fire-maintained plant communities by prescribed fire and also controlled natural fire under Service guidelines and maintaining habitat for trust resources, including listed species through prescribed fire and controlled natural fire (Service 2000, p. 1). The fire management plan for NKDR mentions Bartram's hairstreak and its reliance on its fire-dependent host plant and indicates that "Concern has been raised that fire suppression is contributing to the decline of these species as the host plant requires a fire maintained open pineland to persist (Emmel *et al.* 1995)," (Service 2000, p. 19). However, no specific details are provided to enhance habitat or to avoid or mitigate impacts to Bartram's hairstreak. In addition, management of pine rocklands by NKDR is made particularly difficult by the pattern of land ownership and development; private homes and light commercial uses are embedded within or in close proximity to pineland habitat (Service 2000, p. 10). Hand or mechanical vegetation management at colonies of Bartram's scrub-hairstreak may be necessary at select locations on Big Pine Key (M. Minno, pers. comm. 2009). Anderson (pers. comm. 2010a) suggests that mechanical treatment may be effective in areas that are too dangerous to burn; however, the use of mechanical treatment might cause senescence of croton, since fire is a major driver for germination. Extreme clearing, like that for putting in fire breaks, generates a croton response, which may be a useful technique as a restoration project, but not in areas where an active colony exists (C. Anderson, pers. comm. 2010a).

Salvato (1999, p. 151; 2003, p. 57) indicated that burns are not being administered as thoroughly in Watson's Hammock on Big Pine Key, as is needed to prevent loss of pine rocklands. As a result, much of the pine rocklands within northern Watson's Hammock are being compromised by hardwood hammock (Salvato and Hennessey 2004, p. 225). In addition, fire breaks leading into Watson's Hammock have been expanded; these expansions included cutting back and removing large quantities of native vegetation, including croton (M. Salvato, pers. comm. 2008). During 2009, a fire break on NKDR, running the length of Key Deer Boulevard on Big Pine Key, was mowed by volunteers, thereby cutting back numerous crotons (M. Salvato, pers. comm. 2010). For over a decade the crotons growing within these fire breaks have been actively used by the species (Salvato and Salvato, in press).

The NKDR is attempting to increase the density of host plants within the pine rockland forests through the use of prescribed fire. However, there is a backlog of pine rocklands that need to be burned. Of 318 pine rockland plots that were initially assessed on Big Pine Key in 2005, 110 were not burned, 77 were burned once, 55 were burned twice, and 76 were burned either three or four times since 1960 (Bradley and Saha 2009, p. 22). Complete implementation of a prescribed fire program in the lower Keys has been hampered by an incomplete understanding of the fire ecology in the area, a shortage of resources, and by public opposition to burning. Complicating the issue is that many homes on Big Pine Key have been built in a mosaic of pine rockland, so the use of prescribed fire in many places has become complicated because of potential danger to structures. The Service is working cooperatively with Florida International University in Miami to determine the proper fire frequencies necessary to maintain the pine rockland community on NKDR (Snyder *et al.* 2005, p. iv - v). Only two burns totaling 4 ha (10 ac) were conducted on NKDR in 2009 (A. Morkill, NKDR, pers. comm. 2010). Until more prescribed fires are conducted, fire breaks may provide good habitat on the island because these areas are open, yet mowed or cleared very rarely (C. Anderson, pers. comm. 2010a). For example, Anderson (pers. comm. 2010a) found croton to be at a density of 0.04 plants per m² in the forested plots and 0.27 m² plants per plot on the fire breaks. Overall, lack of appropriate fire management continues to be a threat for this species at NKDR and surrounding lands on Big Pine Key. Future actions should avoid mowing of fire breaks with high densities of host plants and implementing more fire in overgrown areas on NKDR, to the extent possible.

In general, lack of adequate fire management continues to be a threat for this species at NKDR, on surrounding lands on Big Pine Key, and in fragmented pine rocklands where it is difficult to implement prescribed fire. However, NKDR is taking steps to monitor croton before and after fire, protect larvae during burns, and ensure that appropriate corridors are maintained in the small burns it conducts (C. Anderson, pers. comm. 2010a). Fire is essential for persistence of croton, and prescribed fire is essential to minimizing the threat from wildfire (C. Anderson, pers. comm. 2010a). During a wildfire event, managers do not have the ability to consider corridors or burn parameters such as size, heat, smoke, and rate of spread (C. Anderson, pers. comm. 2010a).

Climatic changes and sea level rise are major threats to south Florida, including this species and its habitat. The Intergovernmental Panel on Climate Change (IPCC) reported that the warming of the world's climate system is unequivocal based on documented increases in global average air and ocean temperatures, unprecedented melting of snow and ice, and rising average sea level (IPCC 2007, p. 2; 2008, p. 15). Sea-level rise is the largest climate-driven challenge to low-lying coastal areas and refuges in the sub-tropical ecoregion of southern Florida (U.S. Climate Change Science Program [CCSP] 2008, p. 5-31, 5-32). The long-term record at Key West shows that sea level rose on average 0.088 inches (0.224 cm) annually between 1913 and 2006 (National Oceanographic and Atmospheric Administration [NOAA] 2008, p. 1). This equates to approximately 8.76 inches (22.3 cm) over the last 100 years (NOAA 2008, p. 1).

IPCC (2008, p. 28) emphasized it is very likely that the average rate of sea-level rise during the 21st century will exceed that from 1961 to 2003 (i.e., 0.071 inches [0.18 cm] per year), although it was projected to have substantial geographical variability. Partial loss of the Greenland and, or Antarctic ice sheets could result in many feet (several meters) of sea-level rise, major changes in coastlines, and inundation of low-lying areas (IPCC 2008, p. 28-29). Low lying islands and river deltas will incur the largest impacts (IPCC 2008, p. 28-29). According to CCSP (2008, p. 5-31), much of low-lying, coastal south Florida “will be underwater or inundated with salt water in the coming century.”

IPCC (2008, p. 3, 103) concluded that “climate change is likely to increase the occurrence of saltwater intrusion into coastal aquifers as sea level rises” and that “sea-level rise is projected to extend areas of salinisation of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems in coastal areas.” From the 1930s to 1950s, increased salinity of coastal waters contributed to the decline of cabbage palm forests in southwest Florida (Williams *et al.* 1999, p. 2056-2059), expansion of mangroves into adjacent marshes in the Everglades (Ross *et al.* 2000, p. 9, 12-13), and loss of pine rockland in the Keys (Ross *et al.* 1994, p. 144, 151-155). Hydrology has a strong influence on plant distribution in these and other coastal areas (IPCC 2008, p. 57). Such communities typically grade from salt to brackish to freshwater species. In the Keys, not only are elevation differences between such communities very slight (Ross *et al.* 1994, p. 146), but the horizontal distances are small as well. Human developments will also likely be significant factors influencing whether natural communities can move and persist (IPCC 2008, p. 57; CCSP 2008, p. 7-6).

TNC (2010, p. 1) used high-resolution digital elevation models derived from highly accurate Light Detection and Ranging (LIDAR) remote sensing technology to predict future shorelines and distribution of habitat types for Big Pine Key based on sea level rise predictions ranging from the best-case to worst-case scenarios described in current scientific literature. In the Florida Keys, TNC models predicted that sea level rise will first result in the conversion of habitat, and eventually the complete inundation of habitat. In the best-case scenario, a rise of 7 inches (18 cm) would result in the inundation of 1,840 ac (745 ha) (34 percent) of Big Pine Key and the loss of 11 percent of the island's upland habitat (TNC 2010, p. 1). In the worst-case scenario, a rise of 4.6 feet (140 cm) would result in the inundation of

about 5,950 ac (2,409 ha) (96 percent) and the loss of all upland habitat (TNC 2010, p. 1).

Similarly, using a spatially explicit model for the Keys, Ross *et al.* (2009, p. 473) found that mangrove habitats will expand steadily at the expense of upland and traditional habitats as sea level rises. Most of the upland and transitional habitat in the central portion of Sugarloaf Key is projected to be lost with a 0.2 m-rise (0.7 ft-rise) in sea level; a 0.5-m rise (1.6 ft-rise) in sea level can result in a 95 percent loss of upland habitat by 2100 (Ross *et al.* 2009, 473). Furthermore, Ross *et al.* (2009, p. 471-478) suggest that interactions between sea-level rise and pulse disturbances (e.g., storm surges or fire [see Factor E]) can cause vegetation to change sooner than projected based on sea level alone.

The Science and Technology Committee of the Miami-Dade County Climate Change Task Force (MDCCCTF) (2008, p. 1) recognized that significant sea level rise is a very real threat to the near future for Miami-Dade County. In a January 2008 statement, the MDCCCTF (2008, p. 2-3) warned that sea-level is expected to rise at least 3-5 feet (0.9-1.5 m) within this century. With a 3-4 foot (0.9-1.2 m) rise in sea level (above baseline) in Miami-Dade County: “Spring high tides would be about 6 to 7 feet; freshwater resources would be gone; the Everglades would be inundated on the west side of Miami-Dade County; the barrier islands would be largely inundated; storm surges would be devastating; landfill sites would be exposed to erosion contaminating marine and coastal environments. Freshwater and coastal mangrove wetlands will not keep up with or offset sea level rises of two feet per century or greater. With a five foot rise (spring tides at nearly +8 feet), Miami-Dade County will be extremely diminished.” (MDCCCTF 2008, p. 2-3)

In summary, sporadic occurrences of the butterfly and suitable habitat on unprotected pine rocklands outside of ENP and NKDR largely remain at risk to development, fire suppression, and lack of fire management. This threat is considered to be of high magnitude and imminent. The threat of destruction, modification, or curtailment of habitat due to wildfire and fire management appears to have been lessened in ENP, but continues on NKDR, County, and surrounding private lands. This threat is imminent and of high magnitude. Climatic changes and sea level rise are major threats that will ultimately substantially reduce the extent of habitat, especially in the Keys.

- B. Overutilization for commercial, recreational, scientific, or educational purposes. Rare butterflies and moths are highly prized by collectors and an international trade exists in specimens for both live and decorative markets, as well as the specialist trade that supplies hobbyists, collectors, and researchers (Morris *et al.* 1991, p. 332; Williams 1996, p. 30). The specialist trade differs from both the live and decorative market in that it concentrates on rare and threatened species (Morris *et al.* 1991, p. 333). In general, the rarer the species, the more valuable it is, and prices may exceed U.S. \$2,000 for rare specimens (Morris *et al.* 1991, p. 333).

We do not have direct evidence of collection of Bartram’s hairstreak. Historically, this species has been highly sought after by collectors. It is unlikely that collecting or the threat of collection has ceased. Salvato (pers. comm. 2010) has not seen specimens of the

Bartram's hairstreak listed by the wholesale and specialty insect dealers who offer and sell butterflies to museums, artists, and collectors. However, Salvato (pers. comm. 2010) has been contacted by numerous individuals requesting specimens of the Bartram's hairstreak or in regard to locations where they may be collected in the field. Currently, there is at least one known website that offers specimens for sale (M. Minno, pers. comm. 2009). Thus, there is an established collection pressure for specimens.

Although the hairstreak largely occurs on protected Federal lands, butterfly poaching has occurred on these lands; one individual was found illegally collecting butterflies at Crocodile Lake National Wildlife Refuge in 2008 (A. Morkill, pers. comm. 2008). In the past, when this species was more widespread on Big Pine Key and throughout southern Miami-Dade County, collecting likely exhibited little pressure on this species. At present, even limited collection from the small populations in ENP or NKDR could have deleterious effects on reproductive and genetic viability and thus could contribute to its eventual extinction. Illegal collection could occur in ENP or NKDR without being detected since these areas are not actively patrolled. Similarly, in some areas such as Navy Wells, there is no signage indicating collection is prohibited. Consequently, the potential for unauthorized or illegal collection of eggs, larvae, pupae, and, or adults exists and could go undetected, despite the protection provided on Federal or other public lands.

In summary, we have no direct evidence that collection of Bartram's hairstreak is occurring at present. However, the established interest in specimens and requests for information on its location on the part of collectors, researchers, and others suggests that collection may be occurring and has the potential to occur and become a serious threat to the few remaining populations at any time. Overall, we consider this threat to be likely in the future and of moderate magnitude.

- C. Disease or predation. Hennessey and Habeck (1991, p. 19) collected a fifth-instar larva of Bartram's hairstreak on Big Pine Key from which during pupation a single braconid wasp was produced. This is the only known record for a parasitoid on this species. Tracking the fate of Bartram's hairstreak pupae is extremely difficult because it pupates in the ground litter (Worth *et al.* 1996, p. 63). Collection of other late instar Bartram's hairstreak larvae is needed to determine the influence of parasitism on its early stages (Salvato and Hennessey 2004, p. 225).

In May 2010, Salvato and Salvato (in press) observed two erythraeid larval mite parasites on an adult in Long Pine Key. Although mite predation on butterflies is rarely fatal (Treat 1975, p. 1-362), the role of parasitism by mites in the natural history of the Bartram's hairstreak requires further study. In January 2010, Salvato and Salvato (2010) encountered a crab spider, *Misumenops bellulus* (Aranea: Thomisidae) consuming an early instar larvae of the Florida leafwing (*Anaea troglodyta floridalis*) (Nymphalidae) in the Long Pine Key. Because these crab spiders are frequently observed during surveys for Bartram's hairstreaks on pineland croton, they are likely also a major predator of adults and larvae of this species (Salvato and Hennessey 2004, p. 225; M. Salvato, pers. comm. 2006). Salvato and Salvato (2008, p. 342) have observed dragonflies (Odonata) taking adult Bartram's hairstreaks within

Long Pine Key. Various birds and lizards are also likely natural predators. Although there are several natural predators, we do not know to what extent predation is a threat to Bartram's hairstreak at this time. Minno and Minno (2009, p. 72) cite exotic predators such as ants as a major threat. Exotic ants may be a potential threat, but we do not have data indicating that predation by exotic ants is impacting any population at this time.

We do not have evidence that predation is unusually high or above levels to be expected in nature. The role of parasites and predators in the natural history of the Bartram's hairstreak needs to be investigated. Based upon information available, we do not consider this species to be threatened by disease or predation at this time.

- D. The inadequacy of existing regulatory mechanisms. This species is not listed in the State of Florida. Federal, State, and local laws have not been sufficient to prevent past and ongoing impacts to Bartram's hairstreak or its habitat.

For scientific research on and, or collection of Bartram's hairstreak at ENP and, or NKDR, a permit is required from the NPS or the Service, respectively. Although Bartram's hairstreak occurs on Federal land which offers protection, these areas are vast and open to the public. Public lands can be heavily used, with signage prohibiting collection often lacking and patrolling or monitoring of activities largely absent. Therefore, illegal collection could occur without being detected. Since Bartram's hairstreak is not listed by the State, it is not protected from being killed and from unauthorized take if encountered outside of NKDR or ENP. Consequently, the potential for unauthorized or illegal collection of Bartram's hairstreak (eggs, larvae, pupae, or adults) exists, as discussed under Factor B above and could go undetected, despite its occurrence on Federal lands.

The 1979 Master Plan is the plan of record for ENP, however the NPS is currently preparing a new General Management Plan for ENP (F. Herling, NPS, pers. comm. 2006). The current plan for ENP indicates one goal as "Natural and cultural resources and associated values are protected, restored and maintained in good condition and managed within their broader ecosystem and cultural context" (NPS 2000, p. 10). However, the Master Plan is not regulatory and its implementation is not mandatory.

Similarly, the Comprehensive Conservation Plan (CCP) is the principal guiding document for National Wildlife Refuges, and the Service has developed a CCP for NKDR. This plan specifically addresses strategies for the recovery of the Bartram's hairstreak, Florida leafwing, and Miami blue (*Cyclargus thomasi bethunebakeri*) (C. Anderson, pers. comm. 2010a). It is unknown to what extent NKDR will have the resources necessary to meet its management needs.

At this time, the protection currently afforded Bartram's hairstreak is limited, provides little protection to the species' occupied habitat, and includes no protection of unoccupied habitat. The current management plan at ENP does not specifically address the hairstreak. Although efforts are underway to improve habitat conditions and address life history needs at ENP and NKDR, land management practices do not currently address all of the butterfly's specific life

history needs. Therefore, we conclude that existing regulatory mechanisms are inadequate to protect the Bartram's hairstreak and its habitat; this threat is considered to be of moderate magnitude and imminent.

- E. Other natural or manmade factors affecting its continued existence. Natural or prescribed fire can be a threat to the butterfly. Whereas adults have abilities to move from fire, immature stages (eggs, larvae) are likely to be destroyed by fire (M. Minno, pers. comm. 2009). Large-scale fires (multiple burn blocks) occurring in an extensive area of host plant, fires occurring too frequently, or fires at sensitive times of the species' lifecycle may have serious consequences, given the species' tenuous status. Since few occurrences remain and population size is low, known colonies of Bartram's hairstreak should not be burned entirely. In general, small, manageable burns are preferred. Refugia and corridors with ample areas of host plants and nectar sources should be incorporated into burn plans, wherever possible, and especially in areas of high density butterflies or host plant. Minno (pers. comm. 2009) has noticed that Bartram's hairstreaks are most abundant in forested areas with plentiful pineland croton. Minno (pers. comm. 2009) believes that the butterfly does not seem to like large open areas with croton, such as that which resulted following the wildfire that occurred on Big Pine Key in 2009. Anderson (pers. comm. 2010a), however, notes that the butterfly inhabits some non-forested areas on Big Pine Key. Lack of prescribed fire can also lead to wildfire, which could threaten large areas of croton in one event. Lack of prescribed fire can also make habitat unsuitable for the species.

In August 2007, a prescribed burn of approximately 3.6 ha (9 ac) was conducted at Navy Wells in an area occupied by the Bartram's hairstreak. Although present in the footprint of the burn immediately prior to the fire, surveys soon after the burn failed to locate this species (M. Salvato, pers. comm. 2008). A second burn was conducted at Navy Wells in November 2007 on approximately 10.5 ha (26 ac) in pine rocklands adjacent to the previous burn. The butterfly was not encountered in either location post-burn until early spring 2008 (M. Salvato, pers. comm. 2008). However, following the November burn in Navy Wells, the Bartram's hairstreak ultimately re-colonized the treatment area within 3 to 4 months, indicating a faster recovery time than noted for the species elsewhere (M. Salvato, pers. comm. 2009). Salvato and Salvato (in press) suggested the small sizes of the prescribed fires conducted at Navy Wells and availability of host plant adjacent to the burns sites may have aided the hairstreak in recolonization of the area. During 2008 through 2010, Salvato (pers. comm.) has frequently encountered adults at Navy Wells, including a high of 12 individuals on May 22, 2010. In addition, croton appears to have responded well to prescribed burns conducted throughout the preserve, with fresh croton growth occurring in many locations (M. Salvato, pers. comm. 2010).

For more than a decade Salvato and Salvato (in press) evaluated Bartram's hairstreak abundance at gate 4 in Long Pine Key during the months prior to and following burn events. These studies found significantly more hairstreaks during the months prior to prescribed burns than after the treatments. For example, during June 2001, much of their gate 4 study area, approximately 540 ha (1,334 ac), was burned and possibly as a result, the hairstreak was not observed again at this location for over 6 months.

ENP is currently monitoring the effects of fire on croton, including hairstreak larvae and adults within study plots (see Monitoring). When croton is growing in areas with favorable topography and fuel loading, burning during wet summer conditions can leave a portion of the host plants unburned (A. Land, pers. comm. 2008). Further research is needed to determine the number of unburned refugia needed, as well as size of and distance between refugia.

In years where abundance is especially low, specific areas of occupied habitat may need to be avoided to help safeguard the species over the short- and long-term (S. Perry, pers. comm. 2007; Minno and Minno 2008, p. 1). Fire plans need to be reviewed well in advance of ignition with time to consider any recent changes in butterfly status (S. Perry, pers. comm. 2007). In addition to internal review, plans should be examined annually by species experts so that short-term negative effects from fire (i.e., loss of host plants, loss of eggs and larvae) can be avoided or minimized. If future management activities are not carefully conducted, remaining populations could be depressed further (M. Salvato, pers. comm. 2008; Minno and Minno 2008, p. 1).

As the amount of human activity and size of the human population has increased in south Florida, so has the control of salt marsh mosquitoes (*Aedes sollicitans* (Walker) and *A. taeniorhynchus* (Wiedemann)). To suppress mosquitoes, second-generation organophosphates (naled) and pyrethroid (permethrin) adulticides are used year-round throughout south Florida and from May to November in the Keys by mosquito control districts (Hennessey *et al.* 1992, p. 215; Salvato 1999, p. 10). Despite improved mosquito control practices, the use of adulticides applied using both aerial and ground-based methods present collateral effects on non-target species, including butterflies.

The lethal effect of second-generation organophosphate pesticides, such as naled and fenthion, on non-target Lepidoptera was well noted initially in south Florida and the Keys, with the apparent decline of the endangered Schaus swallowtail butterfly (Emmel and Tucker 1991, p. 19; Eliazar 1992, p. 10). This species' decline in the early 1970s coincided with the expanded use of chemical pesticides by the Monroe County Mosquito Control District (MCMCD), now known as the Florida Keys Mosquito Control District (FKMCD), on the northern Keys (Emmel and Tucker 1991, p. 19; Eliazar 1992, p. 10). When spraying was halted during two periods (1987 and 1989-1992), the species began to recover (Emmel and Tucker 1991, p. 19; Eliazar 1992, p. 10). The swallowtail's immediate decline when applications resumed suggested that chemical pesticides have an adverse effect on non-target species. Studies conducted by Hennessey *et al.* (1992, p. 715) illustrated the presence of spray residue long after application in the habitat of the Schaus swallowtail and several other imperiled butterflies. Baggett (1982, p. 80) believed that the rapid decline in several populations of butterflies in the Keys was directly attributable to mosquito control pesticide applications.

Eliazar (1992, p. 1-52) conducted intensive testing on the effects of naled and fenthion on several south Florida butterfly species. His results indicated that the pesticides and their field

application rates, particularly those of naled, were extremely toxic to non-target Lepidoptera and were being administered in the field at levels above the dosage required to kill target *Aedes* mosquitoes. Eliazar's naled experiments, conducted in the laboratory, included several butterfly species likely to be found in the lower Keys; although it did not include Bartram's hairstreak, it did include the giant swallowtail (*Papilio cresphontes*), the zebra butterfly (*Heliconius charitonia*), the gulf fritillary (*Agraulis vanillae*), and the painted lady (*Vanessa cardui*). His results suggest that naled used at the field application rates would have lethal or at least sublethal effects on Bartram's hairstreak.

In addition, Salvato (1999, p. 1-168; 2001, p. 8-14) measured the toxicity of naled and permethrin on a number of surrogate species and these adulticides were highly toxic towards these butterflies in both immature and adult stages. Furthermore, Salvato (1999, p. 1-168; 2001, p. 8-14; pers. comm. 2006) has been monitoring populations of Bartram's hairstreak on survey transects on Big Pine Key since 1997 and has indicated that numbers of hairstreaks encountered across the island is likely only a fraction of what might occur were adulticide applications more restricted within NKDR lands. According to Salvato (1999, p. 143; 2001, p. 13; pers. comm. 2006), the species' tendency to congregate in large densities on croton flowers along pine rockland clearings and roadsides on Big Pine Key makes the hairstreak far more susceptible than other butterflies to both aerial and truck applied adulticide applications.

Spraying practices by the FKMCD at NKDR have changed to reduce pesticide use over the years. According to the Special Use Permit issued by the Service, the number of aerially applied naled treatments allowed on NKDR has been reduced to a specified allotment (i.e., 9 per mosquito season, no closer than 5 days apart [R. Frakes, Service, pers. comm. 2008]). These changes were made after the Service reviewed the toxicity of naled on federally listed species that occur within NKDR; however, this analysis did not include species of Lepidoptera, since none on NKDR are listed. Since insects are more sensitive to organophosphates than the vertebrate species considered in the analysis, negative impacts to Bartram's hairstreak and other Lepidoptera from continued naled applications will likely occur, despite the reduced use of this insecticide. The Service plans to use information from pesticide studies currently underway (see Conservation Measures) to more fully analyze effects to listed and candidate species on Federal lands.

Two studies were recently implemented to better assess aspects of butterfly toxicology in the Keys. Both confirm that adult mosquito control as practiced in the Keys (both aerial and ground applications) pose some threat to butterflies, and one shows that mortality of the Miami blue butterfly increases in areas affected by standard aerial adulticiding procedures alone. Zhong (2009, p. 1-32) conducted a study to directly investigate the impact of naled ultra-low volume (ULV) aerial spray for mosquito control on Miami blue larvae on leaves in the field. The study was conducted in North Key Largo. Following experimental trials, survival of Miami blue larvae was approximately 77, 90, and 100 percent in the target zone, spray drift zone, and control stations (Zhong 2009, p. 2). Survival of larvae was determined by exposure level of available insecticide, with residue level in the air column (as opposed to ground deposition values) particularly critical (Zhong 2009, p. 14). Mortality of larvae was

strongly correlated with naled residue on yarn (the medium used to sample air column residue) ($r = 0.721$, $p < 0.001$). The correlation with naled residue on filter paper (the medium used to sample ground deposition of residue) was weaker ($r = 0.504$, $p < 0.001$) (Zhong 2009, p. 17). Zhong (2009, p. 17) noted that “The spray impacts on butterfly larvae could be very substantial in the targeted spray zone as evident with up to 100 percent butterfly larval mortality found on some locations within treated areas”. Overall, this report shows a statistically significant effect of mosquito control on survival of Miami Blue larvae (R. Frakes, Service, pers. comm. 2009).

The small outlying areas of NKDR have been designated no-spray zones by agreement between the Service and FKMCD. The Service is working towards expanding no-spray zones (A. Morkill, pers. comm. 2010). However, substantial areas of the pine rocklands within NKDR except Watson’s Hammock on Big Pine Key are sprayed with naled (aerially applied adulticide); additionally, residential areas and roadsides across Big Pine Key are treated with permethrin (ground-based applied adulticide) (Salvato 2001, p. 10). In short, substantial areas of Big Pine Key, except Watson’s Hammock and Cactus Hammock, are sprayed with naled or permethrin. Therefore, Bartram’s hairstreak and its habitat on Big Pine Key are directly exposed to adulticides used for mosquito control.

Designation of no-spray zones, however, does not prevent chemical intrusion. When these zones were created in 1989, pesticide drift downwind into them had not been documented. However, Hennessey *et al.* (1992, p. 715) detected naled residues 750 m (2,460 feet) into the no-spray zone at Watson’s Hammock and 150 m (492 feet) at Cactus Hammock. Truck-applied ultra-low-volume (ULV) fenthion, sprayed primarily in residential areas, did not appear to drift into non-target areas. This study indicated that naled remained in the habitat well into midday, posing risk to diurnally active non-target species, such as Bartram’s hairstreak. In a more recent study by Florida A&M University involving the candidate Miami blue butterfly in north Key Largo, substantial amounts of drift have also been reported. Preliminary results of that study have demonstrated drift up to four miles from the application site; however, it is not yet known if adverse impacts occur at the residue level detected at that distance from the application zone (R. Frakes, pers. comm. 2008). Therefore, Bartram’s hairstreaks utilizing Watson’s Hammock on Big Pine Key are exposed to chemical residues from aerial application of pesticides despite its location within a no-spray zone.

Pierce (2009, p. 1-20) is conducting a study to determine the concentration and persistence of mosquito control adulticides within NKDR on Big Pine Key. Permethrin was found to drift considerable distances from the application area and to persist for weeks after application (Pierce 2009, p. 15). The average half-life for permethrin on foliage was 60 hours, and permethrin concentrations approached 250 ng/g leaf, indicating that permethrin would be present on leaves in concentrations near 1 ng/g leaf after 20 days (Pierce 2009, p. 15). With weekly or bi-weekly permethrin applications within the residential communities, foliage within and adjacent to residential communities retained high concentrations of permethrin throughout the mosquito pesticide application season (Pierce 2009, p. 15-16). In addition, permethrin concentrations observed at a “no spray” control site indicated considerable drift from truck applications in nearby residential communities, suggesting the need for additional

monitoring to assess the extent of drift and the persistent concentrations of permethrin that are impacting remote (and residential) areas of the NKDR (Pierce 2009, p. 16). Naled also was observed to drift into non-application areas, but the persistence was much less than permethrin; half-life was about 6 hours (Pierce 2009, p. 15). Overall, the persistence of permethrin on foliage resulted in simultaneous exposure to foliage-eating non-target organisms, even when naled was applied at a later date. These results raise the concern for synergistic effects from simultaneous exposure to permethrin, naled, and dichlorvos (Pierce 2009, p. 16). These findings suggest that truck-based applications of adulticides through aerial and truck applications, may pose a threat to Bartram's hairstreak.

In general, Long Pine Key does not appear to be regularly impacted by mosquito control practices, except for the use of adulticides (e.g., Sumithrin [Anvil]) in residential areas and campgrounds. Housing areas, maintenance areas, outside work areas for park maintenance staff and contractors, and areas near buildings have been sprayed in the past (S. Perry, pers. comm. 2007, M. Salvato pers. comm. 2010). In addition, there are reports that operators frequently leave the foggers on when traveling from one area to another within ENP (S. Perry, pers. comm. 2007). However, there are no recent reports of this type of activity occurring within ENP (M. Salvato, pers. comm. 2010). Spraying has occurred following hurricanes (S. Perry, pers. comm. 2008). In 2009, however, no spraying was conducted in or near Long Pine Key (M. Salvato, pers. comm. 2010). Perry (pers. comm. 2008) believes it is important that spraying does not occur in or near the pinelands or in coastal areas of ENP. Sporadic Bartram's hairstreak populations adjacent to and outside ENP in suitable and potential habitat within Miami-Dade County are vulnerable to the lethal and sublethal effects of adulticide applications.

Butterflies in south Florida and the Keys, such as Bartram's hairstreak, have adapted over time to the influence of tropical storms and other forms of adverse weather conditions (Salvato and Salvato 2007, p. 154). However, given the substantial reduction in the Bartram's hairstreak's historic range in the past 50 years, the threat and impact of tropical storms and hurricanes on the remaining populations is much greater than when its distribution was more widespread. In October 2005, Watson's Hammock on Big Pine Key was heavily damaged from Hurricane Wilma. Native vegetation across much of Watson's Hammock, including croton, was slow to recover. The Bartram's hairstreak was observed again in Watson's Hammock during 2008 and 2009 (Salvato, pers. comm. 2009). According to the National Oceanographic and Atmospheric Administration, Miami-Dade County, the Keys, and western Cuba are the most storm-prone areas in the Caribbean so this threat is expected to continue.

In addition, unusually cold temperatures were encountered throughout southern Florida during winter of 2010. Frost in January 2010 resulted in substantial die back of native plants and resulted in damage and widespread defoliation of pineland croton in Long Pine Key (J. Sadle, pers. comm. 2010c; A. Land, pers. comm. 2010; Hallac *et al.* 2010, p. 2-3). Larval Florida leafwings were impacted by the cold as approximately 50 percent of the individuals were observed to be dead or without nearby food supplies at three locations within Long Pine Key (Hallac *et al.* 2010, p. 3). It is not clear if or how Bartram's hairstreaks may have been

impacted by the event within ENP. Larvae unable to successfully reach healthier adjacent host plants likely perished. Sadle (pers. comm. 2009) also noted frost damage on croton in Long Pine Key in 2009, but observed living Bartram's hairstreak and Florida leafwing larvae on February 5, 2009 when temperatures were at or barely above freezing (36 F in Homestead, frost on the ground in Long Pine Key). It is not clear what the short or long-term impacts of prolonged cold periods may be on Bartram's hairstreak populations; it is likely that prolonged cold periods have some negative impacts on both the species and its host plant (J. Sadle, pers. comm. 2009, A. Land, pers. comm. 2010). Minno and Minno (2009, p. 72) indicates that extreme weather events (e.g., hurricanes, droughts, and freezes) are major threats.

The most recent population estimates were provided by Schweitzer in 2003. No recent data is available. Schweitzer's data demonstrates that the Bartram's hairstreak is vulnerable to extinction because its populations are small and isolated. A population of 1,000 has been suggested as marginally viable for an insect, although this is likely highly dependent upon type of species (D. Schweitzer, The Nature Conservancy, pers. comm. 2003). Schweitzer (pers. comm. 2003) has also suggested that butterfly populations of less than 200 adults per generation would have difficulty surviving over the long-term. Therefore, the Bartram's hairstreak populations appear to be at risk.

In general, isolation, whether caused by geographic distance, ecological factors, or reproductive strategy, will likely prevent the influx of new genetic material and can result in a highly inbred population with low viability and/or fecundity (Chesser 1983, p. 68). Natural fluctuations in rainfall, host plant vigor, or predation may weaken a population to such an extent that recovery to a viable level would be impossible. Isolation of habitat can prevent recolonization from other sites and result in extinction. Distance between populations and the small size of highly sporadic populations make recolonization unlikely if populations are extirpated. Fragmentation of habitat and the limited dispersal capabilities of this butterfly lead us to believe this species is vulnerable because of the small number of populations, their small size, and their relative isolation.

In summary, the Bartram's hairstreak is vulnerable to a wide array of natural and human factors. Fire can cause mortality of immature stages. Large-scale fires (multiple burn units or without refugia), fires occurring too frequently (e.g., < 3 years or before recovery), or fires at sensitive times may have severe impacts on the species, given its current tenuous status. We find overall the threat of fire is severe and imminent. Application of mosquito control pesticides are likely a threat to the butterfly, in areas outside of ENP. This threat is of high magnitude and imminent. Hurricanes, prolonged cold events, small population size, and few, isolated occurrences in a restricted range are also serious threats. We find this threat is of moderate magnitude and imminent.

CONSERVATION MEASURES PLANNED OR IMPLEMENTED

Fire management practices on pine rocklands within ENP and potentially NKDR may provide benefits for the Bartram's hairstreak. The Florida Comprehensive Wildlife Conservation Strategy discusses management of pine rocklands, but has not been implemented or funded

(FWC 2005, p. 283-286). The NPS is in the process of mapping pineland croton within ENP (J. Sadle, pers. comm. 2010b) and has established croton monitoring plots (see Monitoring below). The NKDR is mapping areas of croton and expanding its efforts to use prescribed fire. Two burns totaling 4 ha (10 ac) were conducted on NKDR in 2009 (A. Morkill, pers. comm. 2010). In addition, Miami-Dade County is working with Fairchild Tropical Botanic Garden (FTBG) to implement a fire monitoring program at its preserves (Possley and Maschinski 2007, 1-13; J. Maguire, pers. comm. 2008b). As part of this program, croton will be mapped and fire effects will be studied (J. Maguire, pers. comm. 2008a; Possley and Maschinski 2007, p. 3).

The Service has funded a comprehensive laboratory study with Florida International University to refine knowledge of the toxicology and effects of naled and permethrin. Specific objectives of this study are to: (1) determine the toxicity of naled and permethrin to different stages of the life cycle of butterflies at environmentally relevant concentrations of insecticides and (2) conduct a probabilistic ecological risk assessment for butterflies by comparing species sensitivity distributions for naled, dichlorvos, and permethrin with exposure distributions for each insecticide at different sites. The Service has also provided funding to Mote Marine Laboratory to better estimate toxicological effects in the field. Specific objectives of this study are to: (1) determine mosquito adulticide distribution, concentrations, and persistence in the field following routine mosquito control operations and (2) provide empirical data from field studies for comparison with laboratory toxicity studies of mosquito adulticide effects on lepidopteran species. In addition, a Service representative participated in the field study with Florida A&M University, which tested the effects of adulticides on the Miami blue butterfly, including the amount of deposition and extent of drift. The Service will have a better understanding of the risk to its trust resources by some mosquito control practices following completion of these studies. In addition, the Service is attempting to expand no-spray zones in the Keys. The Service is seeking additional funding to determine the extent of permethrin drift and accumulation within NKDR (A. Morkill, pers. comm. 2009).

The Florida Comprehensive Wildlife Conservation Strategy discusses management of pine rocklands, but has not been implemented or funded (FWC 2005, p. 283-286).

SUMMARY OF THREATS

The Bartram's hairstreak occurs in ENP, NKDR, and a few other locations. Habitat of the hairstreak, pine rocklands, is globally imperiled and dependent upon fire. Inappropriate fire management or wildfire could destroy immature stages and impact the availability of pineland croton, its sole host plant. Fire suppression or inability to conduct prescribed fire may also result in loss of habitat. Climatic changes and sea level rise are long-term threats that will continue; these factors are expected to impact pine rocklands and ultimately reduce the extent of available habitat, especially in the Keys. In addition, the Bartram's hairstreak and its habitat are vulnerable to a wide variety of natural and human factors. Mosquito control practices are a threat to the population on Big Pine Key and within Miami-Dade County. Small, isolated populations and other sporadic and localized occurrences are exposed to extreme weather events (e.g., hurricanes, prolonged cold temperatures). Further reduction of the populations and associated localized occurrences, especially due to catastrophic weather, pesticide application, loss of suitable habitat, or lack of prescribed fire or inappropriate fire management could

severely reduce the likelihood of this butterfly's survival. Finally, the established interest in hairstreak specimens and information requests regarding its location on the part of collectors, researchers, and others suggests that collection may be occurring and has the potential to occur at any time. At the present time, there is insufficient information to conclude that the species is currently threatened by overutilization for commercial, recreational, scientific, or educational purposes. We find that this species is warranted for listing throughout all of its range, and, therefore, find that it is unnecessary to analyze whether it is threatened or endangered in a significant portion of its range.

RECOMMENDED CONSERVATION MEASURES

- Frequent monitoring of populations is necessary (M. Minno, pers. comm. 2009; C. Anderson, pers. comm. 2010a).
- Review and adjust fire management practices as needed to help maintain or expand the population sizes or numbers of populations. Continue to review and seek input on proposed burn plans on an annual basis from species experts. Coordinate activities among fire crews, biologists, and lepidopterists and use adaptive management as needed.
- Continue to establish buffer zones with croton as refugia during prescribed fire. In years where abundance is low, specific areas of occupied habitat may need to be avoided to help safeguard the species over the short- and long-term (S. Perry, pers. comm. 2007; Minno and Minno 2008, p. 1, Salvato, pers. comm. 2010). Conduct research to assess the efficacy of buffer zones (C. Anderson, pers. comm. 2010a; J. Sadle, pers. comm. 2010c).
- Protect remnant patches of pine rocklands and use prescribed fire to restore native plant diversity. Pine rocklands in Miami-Dade County may continue to support Bartram's hairstreak; these areas should not be burned until burned areas recover. Miami-Dade County has implemented needed measures to protect imperiled butterflies (M. Salvato, pers. comm. 2010).
- Determine the distribution and abundance of pineland croton within ENP.
- Restore pineland croton to relict fragments of pine rocklands within the hairstreak's historic range to expand its occupied habitat.
- Address concerns regarding impacts of mosquito control activities in relation to pine rockland habitats on NKDR and adjacent properties. Establish additional no-spray zones and wider buffer areas around these zones.
- Continue to participate and contribute to the Imperiled Butterfly Working Group, which is aimed at conserving south Florida's imperiled butterflies.
- Examine the role of parasites and predators in the life history of the butterfly.
- Evaluate the need for establishment of *ex situ* conservation populations in the laboratory (J. Sadle, pers. comm. 2010a). If pursued, ensure that this action is consistent with the Service's captive propagation and reintroduction policy and that adequate funding and support would be available. Previous captive propagation and reintroduction efforts for other imperiled butterflies in Florida have been largely unsuccessful.

LISTING PRIORITY

--

THREAT			
Magnitude	Immediacy	Taxonomy	Priority
High	Imminent	Monotypic genus	1
		Species	2
		Subspecies/population	3*
	Non-imminent	Monotypic genus	4
		Species	5
		Subspecies/population	6
Moderate to Low	Imminent	Monotypic genus	7
		Species	8
		Subspecies/population	9
	Non-imminent	Monotypic genus	10
		Species	11
		Subspecies/population	12

Rationale for listing priority number:

Magnitude: The Bartram's hairstreak is threatened by the combined influences of habitat destruction and modification from continued loss of unprotected pine rocklands and wildfire or fire management on protected sites. Climatic changes and sea level rise are serious long-term threats that will reduce the extent of habitat. Mosquito control activities are a threat to the butterfly on Big Pine Key, including NKDR, and within Miami-Dade County. Loss of genetic diversity may be a problem for the butterfly considering its small, fragmented, and isolated populations. The probability for catastrophic events (e.g., hurricanes, prolonged cold events) and the possibility of accidental harm or habitat destruction are threats due to small population sizes and limited numbers at the few remaining locations. In addition to these threats, inadequate regulatory protection continues to pose threats to the species throughout its historic range. We also recognize that illegal collection is a potential threat to the species. Overall, we find that these threats are of high magnitude.

Imminence: The Bartram's hairstreak occurs in only a few locations. The threats of habitat destruction and modification are occurring with the continued loss of unprotected pine rocklands and wildfire or fire management on protected sites. Sea level rise is currently occurring and has resulted in the loss of pine rocklands. However, this is considered a long-term threat since we do not have evidence that it is currently affecting any population. This butterfly is likely negatively impacted by adulticides used for mosquito control on Big Pine Key and outside of ENP. The threat from loss of genetic diversity within small, fragmented, and isolated populations is expected to continue. The likelihood of extreme weather or catastrophic events (e.g., hurricanes, prolonged cold periods) to remaining populations seriously threatens the survival of this butterfly, and these threats are expected to continue. We find these threats to be currently occurring and imminent. In addition, since there is an established interest in locations and desire for specimens by collectors, researchers, and others, we believe this species may be at risk; collection may be occurring and has the potential to occur unnoticed at any time, since areas are

remote and open to the public. Overall, we find the immediacy of these threats to be imminent.

Rationale for Change in Listing Priority Number (insert if appropriate)

Yes Have you promptly reviewed all of the information received regarding the species for the purpose of determining whether emergency listing is needed?

Is Emergency Listing Warranted? No, however, status needs to be carefully monitored. The status and distribution of this butterfly needs to be monitored closely to detect change and any further decline. The loss or decline of any occurrence(s) would be detrimental to the status of the species. The Service and its partners need to continue to implement actions to conserve this species, remove threats, and increase viability wherever possible.

DESCRIPTION OF MONITORING

Surveys for Bartram's hairstreak are ongoing. Monitoring by Salvato began in 1997 and has been conducted either monthly or bi-monthly at various locations within the butterfly's historic range (Salvato 1999, p. 1-168; 2001, p. 8-14, pers. comm. 2008). In addition, Perry has conducted periodic surveys in ENP. Surveys by other lepidopterists, agency personnel, and members of the North American Butterfly Association (NABA) occur on a periodic basis.

ENP Fire Management initiated fire effects monitoring of pineland croton in 2005. This monitoring effort was started to provide preliminary information on pineland croton and butterfly response to fire for ENP's adaptive management program (A. Land, pers. comm. 2007, 2008). Two study plots have been established. Biologists visit each plot monthly to measure pineland croton height and crown area, count the number of flowers and fruits, and to note the presence of eggs, larvae, and herbivory (A. Land, pers. comm. 2007, 2008, 2010). Adults are also recorded if observed within the plot. Monitoring is continuing.

NKDR is monitoring all host plants before and after fire to check for larvae to better understand plant/butterfly response (C. Anderson, pers. comm. 2010a). NKDR will start a population monitoring program this year (C. Anderson, pers. comm. 2010a).

Miami-Dade County is working with FTBG to implement a fire monitoring program at its preserves (J. Maguire, pers. comm. 2008b; Possley and Maschinski 2007, 1-13). The effects of fire on croton will be examined (J. Maguire, pers. comm. 2008a; Possley and Maschinski 2007, p. 3). To date, the Service has not received any data for this program.

COORDINATION WITH STATES

Indicate which State(s) (within the range of the species) provided information or comments on the species or latest species assessment: The Service requested new information (observations, data, reports) regarding the status of this species and any new information regarding threats to this species from: Florida Department of Agriculture and Consumer Services, Florida Department of Environmental Protection, FWC, U.S. Geological Survey, U.S. Environmental Protection Agency, National Park Service, Service (Ecological Services and National Wildlife Refuges), FNAI, Archbold Biological Station, IRC, UF, Florida International University,

Randolph-Macon College, mosquito control districts, NABA, and other entities. In total, the previous assessment was sent to approximately 116 individuals.

The Bartram's hairstreak is recognized in Florida's Comprehensive Wildlife Conservation Strategy as one of Florida's species of greatest conservation need (FWC 2005, p. 91).

Indicate which State(s) did not provide any information or comments: Florida.

LITERATURE CITED

- Anderson, C. 2009. Email to Anne Morkill. U.S. Fish and Wildlife Service. Florida Keys National Wildlife Refuge Complex. Big Pine Key, Florida. March 23, 2009.
- Anderson, C. 2010a. Email to Paula Halupa (comments on Bartram's hairstreak species assessment). U.S. Fish and Wildlife Service, Florida Keys National Wildlife Refuge Complex. Big Pine Key, Florida. February 10, 2010.
- Anderson, C. 2010b. Meeting with South Florida Ecological Services Office. U.S. Fish and Wildlife Service, Florida Keys National Wildlife Refuge Complex. Big Pine Key, Florida. April 28, 2010.
- Baggett, H.D. 1982. Order Lepidoptera. *In* R. Franz (ed.), Invertebrates. *In* P. C. Pritchard (ed.) Rare and Endangered Biota of Florida. Volume 6. Invertebrates, pages 78-81. University Press, Gainesville, Florida.
- Bergh, C., and J. Wisby. 1996. Fire history of the lower Keys pine rocklands. Nature Conservancy (publishers). Key West, Florida
- Bradley, K.A., and S. Saha. 2009. Post-hurricane responses of rare plant species and vegetation of pine rocklands in the Lower Florida Keys. Report submitted to U.S. Fish and Wildlife Service, Big Pine Key, Florida. The Institute for Regional Conservation. Miami, Florida.
- Calhoun, J.V., J.R. Slotten, and M.H. Salvato. 2002. Rise and fall of tropical blues in Florida: *Cyclargus ammon* and *Cyclargus thomasi bethunebakeri* (Lepidoptera: lycaenidae). *Holarctic Lepidoptera* 7(1):13-20.
- Carlson, P.C., G.W. Tanner, J.M. Wood, and S.R. Humphrey. 1993. Fires in Key deer habitat improves browse, prevents succession, and preserves endemic herbs. *Journal of Wildlife Management* 57:914-928.
- Chesser, R.K. 1983. Isolation by distance: relationship to the management of genetic resources. Pages 66-77 *in* S. Schonewald-Cox, M. Chambers, B. MacBryde, and L. Thomas (eds), Genetics in conservation: a reference for managing wild animal and plant populations. The Benjamin/Cummings Publishing Company, Inc.
- Dickson, J.D. 1955. An ecological study of the Key Deer. Florida Game and Freshwater Fish Commission. Pittmann-Robertson Project Technical Bulletin 3.
- Eliazar, J.E. 1992. Effect of two mosquito adulticides, naled and fenthion, on selected nontarget lepidopteran species. M.S. Thesis. University of Florida, Gainesville, Florida.
- Emmel, T.C., and J.C. Tucker (eds). 1991. Mosquito control pesticides: ecological importance

- and management alternatives. Scientific Publishers, Inc. Gainesville, Florida.
- Emmel, T.C. R.A. Worth and K. Schwarz. 1995. The relationships between host plant and habitat for the distribution of three potentially endangered south Florida butterfly species. Report to the National Biological Survey.
- Florida Fish and Wildlife Conservation Commission. 2005. Florida's Wildlife Legacy Initiative. Florida's Comprehensive Wildlife Conservation Strategy. Tallahassee, Florida.
- Florida Natural Areas Inventory. 2009. FNAI Element Tracking Summary. Tallahassee, Florida. March 4, 2009.
- Florida Natural Areas Inventory. 2010. FNAI element tracking summary. Tallahassee, Florida. March 30, 2010. http://www.fnai.org/PDF/Element_tracking_summary_201003.pdf [Accessed: May 24, 2010]
- Folk, M.L. 1991. Habitat of the Key deer. Ph.D. Dissertation, Department of Zoology. Southern Illinois University, Carbondale, Illinois.
- Frakes, R. 2008. Conversation with Paula Halupa. U.S. Fish and Wildlife Service, South Florida Ecological Services Office. Vero Beach, Florida. March 19, 2008.
- Frakes, R. 2009. Email to Paula Halupa. U.S. Fish and Wildlife Service, South Florida Ecological Services Office. Vero Beach, Florida. April 27, 2009.
- Hallac, D., J. Kline, J. Sadle, O. Bass, T. Ziegler, and S. Snow. 2010. Preliminary effects of the January 2010 cold weather on flora and fauna in Everglades National Park. Biological Resources Branch, South Florida Natural Resources Center, Everglades and Dry Tortugas National Parks, Homestead, Florida. February 2, 2010.
- Hennessey, M.K., and D.H. Habeck. 1991. Effects of mosquito adulticiding on populations of non-target, terrestrial arthropods in the Florida Keys. United States Department of Agriculture - Agricultural Research Service. Miami, Florida.
- Hennessey, M.K., H.N. Nigg, and D.H. Habeck. 1992. Mosquito (Diptera: Culicidae) adulticide drift into wildlife refuges of the Florida Keys. Environmental Entomology 21(4):715-720.
- Herling, F. 2006. Email to Paula Halupa. Everglades and Dry Tortugas National Parks. Homestead, Florida. March 7, 2006.
- Hodges, S.R., and K.A. Bradley. 2006. Distribution and population size of five candidate plant taxa in the Florida Keys: *Argythamnia blodgettii*, *Chamaecrista lineata* var. *keyensis*, *Indigofera mucronata* var. *keyensis*, *Linum arenicola*, and *Sideroxylon reclinatum* subsp.

austrofloridense. The Institute for Regional Conservation. Final Report Contract Number 401815G011. Miami, Florida.

- Intergovernmental Panel on Climate Change. 2007. Summary for policymakers, In: Climate Change 2007: the Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller, Editors]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Intergovernmental Panel on Climate Change. 2008. Climate Change and Water [B.C. Bates, Z.W. Kundzewicz, S. Wu, and J.P. Palutikof, Editors]. Technical Paper of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change Secretariat, Geneva, Switzerland.
- Integrated Taxonomic Information System. 2010. ITIS standard report page: *Strymon acis bartrami* <http://www.itis.gov/servlet/SingleRpt/SingleRpt>. [Accessed: May 24, 2010]
- Land, A. 2007. Email to Paula Halupa. Everglades National Park Fire Effects. Everglades National Park. Homestead, Florida. December 13, 2007.
- Land, A. 2008. Email to Paula Halupa. Everglades National Park Fire Effects. Everglades National Park. Homestead, Florida. December 20, 2008.
- Land, A. 2010. Email to Paula Halupa (comments on species assessment). Everglades National Park Fire Effects. Everglades National Park. Homestead, Florida. January 22, 2010.
- Loope, L.L., and V.L. Dunevitz. 1981. Impact of fire exclusion and invasion of *Schinus terebinthifolius* on limestone rockland pine forests of southeastern Florida. South Florida Resource Center. Report T-645, National Park Service. Everglades National Park, Homestead, Florida.
- Maguire, J. 2008a. Telephone conversation with Paula Halupa. Miami-Dade Parks and Recreation Department. Miami, Florida. January 31, 2008.
- Maguire, J. 2008b. Email to Paula Halupa. Miami-Dade Parks and Recreation Department. Miami, Florida. January 31, 2008.
- Maguire, J. 2010. Email to Mark Salvato, Miami-Dade Parks and Recreation Department, Miami, FL. April 28, 2010.
- Miami-Dade County Climate Change Task Force, Science and Technology Committee. 2008. Statement on sea level in the coming century. January 17, 2008. Miami-Dade County, Florida.

- Minno, M. 2007. Email to Paula Halupa. Eco-Cognizant, Inc. Gainesville, Florida. March 8, 2007.
- Minno, M. 2009. Email to Paula Halupa. Eco-Cognizant, Inc. Gainesville, Florida. February 16, 2009.
- Minno, M.C., and T.C. Emmel. 1993. Butterflies of the Florida Keys. Scientific Publishers, Inc., Gainesville, Florida.
- Minno, M., and M. Minno. 2008. Proposal. The effects of fire on two Federal candidate butterflies in Everglades National Park, Florida. Eco-Cognizant, Inc. Gainesville, Florida. In cooperation with Dr. Sue Perry, South Florida Natural Resources Center Everglades National Park. November 12, 2008.
- Minno, M., and M. Minno. 2009. A plan to conserve rare butterflies in the Florida Keys. Submitted to: Edsel M. Fussel, Director, Florida Keys Mosquito Control District. Eco-Cognizant, Inc. Gainesville, Florida.
- Morkill, A. 2008. Email to Steve Klett. U.S. Fish and Wildlife Service, Florida Keys National Wildlife Refuge Complex. Big Pine Key, Florida. March 12, 2008.
- Morkill, A. 2009. Email to Dana Hartley. U.S. Fish and Wildlife Service, Florida Keys National Wildlife Refuge Complex. Big Pine Key, Florida. December 15, 2009.
- Morkill, A. 2010. Meeting with South Florida Ecological Services Office. U.S. Fish and Wildlife Service, Florida Keys National Wildlife Refuge Complex. Big Pine Key, Florida. April 28, 2010.
- Morris, M.G., N.M. Collins, R.T. Vane-Wright, and J. Waage. 1991. The utilization and value of non-domesticated insects. Pages 319-347 *in* Collins, N.M. and J.A. Thomas (eds), The Conservation of Insects and Their Habitats, Academic Press, London.
- National Oceanographic and Atmospheric Administration. 2008. Sea Levels Online (Mean sea level trend 8724580 Key West, Florida). National Ocean Service, Center for Operational Oceanographic Products and Services. Online [<http://tidesandcurrents.noaa.gov>]. [Accessed: October 17, 2008].
- National Park Service. 2000. Everglades National Park Strategic Plan. 2001–2005. U.S. Department of the Interior, National Park Service, Everglades National Park, Homestead, Florida.
- National Park Service. 2005. Fire Management Plan for Everglades National Park (Park Review Draft). U.S. Department of the Interior, National Park Service. Everglades National Park, Homestead, Florida.


- NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. <http://www.natureserve.org/explorer>. [Accessed: May 24, 2010].
- O'Brien, J.J. 1996. Habitat preferences of rare and common *Galactia* native to south Florida pine rocklands. M.S. Thesis. Florida International University, Miami, Florida.
- Olson, M.S., and W.J. Platt. 1995. Effects of habitat and growing season fires on resprouting of shrubs in longleaf pine savannas. *Vegetatio* 119:101-118.
- Opler, P.A., and G.O. Krizek. 1984. Butterflies east of the Great Plains. The John Hopkins University Press, Baltimore, Maryland.
- Pelham, J. P. 2008. A catalog of the butterflies of the United States and Canada with a complete bibliography of the descriptive and systematic literature. *Journal of Research on the Lepidoptera* 40: 231.
- Perry, S. 2007. Email from Sue Perry, Everglades National Park, to Paula Halupa, transmitting comments from the biological staff of Everglades National Park on the update of the species assessments for Bartram's hairstreak and Florida leafwing butterflies. Homestead, Florida. December 18, 2007.
- Perry, S. 2008. Email to Paula Halupa. Everglades National Park. Homestead, Florida. December 15, 2008.
- Pierce, R.H. 2009. Determine direct and indirect effects of mosquito control pesticides on listed species inhabiting DOI managed lands in the Florida Keys. Cooperative Agreement 401816J092. Progress report October 1, 2007 to September 30, 2009. Mote Marine Laboratory, Sarasota, Florida.
- Platt, W.J., R.F. Doren, and T. Armentano. 2000. Effects of Hurricane Andrew on stands of slash pine (*Pinus elliottii* var. *densa*) in the Everglades region of south Florida (USA). *Plant Ecology* 146:43-60.
- Possley, J. and J. Maschinski. 2007. Draft proposal. Fire monitoring protocol for Miami-Dade County Preserves. Fairchild Tropical Botanic Garden. Center for Tropical Plant Conservation. Coral Gables, Florida.
- Pyle, R.M. 1981. The Audubon Society field guide to North American butterflies. Alfred A. Knopf, New York.
- Ross, M.S., J.F. Meeder, J.P. Sah, P.L. Ruiz and G.J. Telesnicki. 2000. The southeast saline Everglades revisited: 50 years of coastal vegetation change. *Journal of Vegetation Science* 11:101-112.

- Ross, M.S., J.J. O'Brien, and L. da Silveira Lobo Sternberg. 1994. Sea-level rise and the reduction in pine forests in the Florida Keys. *Ecological Applications* 4:144-156.
- Ross, M.S., J.J. O'Brien, R.G. Ford, K. Zhang, and A. Morkill. 2009. Disturbance and the rising tide: the challenge of biodiversity management on low-island ecosystems. *Frontiers in Ecology and the Environment* 7(9): 471–478.
- Sadle, J. 2007. Email from Sue Perry, Everglades National Park, to Paula Halupa, transmitting comments from the biological staff of Everglades National Park on the update of the species assessments for Bartram's hairstreak and Florida leafwing butterflies. Homestead, Florida. December 18, 2007.
- Sadle, J. 2009. Email to Marc Minno. Everglades National Park. Homestead, Florida. March 9, 2009.
- Sadle, J. 2010a. Email to Paula Halupa (comments on species assessment [Bartram's hairstreak]). Everglades National Park. Homestead, Florida. January 28, 2010.
- Sadle, J. 2010b. Email and telephone conversation with Dana Hartley and Paula Halupa. Everglades National Park. Homestead, Florida. February 16, 2010.
- Sadle, J. 2010c. Email to Paula Halupa (comments on species assessment [Florida leafwing]). Everglades National Park. Homestead, Florida. January 28, 2010.
- Salvato, M.H. 1999. Factors influencing the declining populations of three butterfly species in South Florida and the lower Florida Keys. M.S. Thesis. University of Florida, Gainesville, Florida.
- Salvato, M.H. 2001. Influence of mosquito control chemicals on butterflies (Nymphalidae, Lycaenidae, Hesperidae) of the lower Florida Keys. *Journal of the Lepidopterists' Society* 55(1):8-14.
- Salvato, M.H. 2003. Butterfly conservation and host plant fluctuations: the relationship between *Strymon acis bartrami* and *Anaea troglodyta floridalis* on *Croton linearis* in Florida (Lepidoptera: Lycaenidae and Nymphalidae). *Holarctic Lepidoptera* 10(1-2):53-57.
- Salvato, M.H. 2006. Comments on species assessment. U.S. Fish and Wildlife Service, South Florida Ecological Services Office. Vero Beach, Florida. February 8, 2006.
- Salvato, M.H. 2007. Email to Paula Halupa. U.S. Fish and Wildlife Service, South Florida Ecological Services Office. Vero Beach, Florida. October 1, 2007.
- Salvato, M.H. 2008. Comments on species assessment. U.S. Fish and Wildlife Service, South Florida Ecological Services Office. Vero Beach, Florida. March 13-16, 2008.

- Salvato, M.H. 2009. Email to Paula Halupa. U.S. Fish and Wildlife Service, South Florida Ecological Services Office. Vero Beach, Florida. April 16, 2009.
- Salvato, M.H. 2010. Comments on species assessment. U.S. Fish and Wildlife Service, South Florida Ecological Services Office. Vero Beach, Florida. May 16 – June 10, 2010.
- Salvato, M.H., and M.K. Hennessey. 2003. Notes on the historic range and natural history of *Anaea troglodyta floridalis*. Journal of the Lepidopterists' Society 57(3):243-249.
- Salvato, M.H., and M.K. Hennessey. 2004. Notes on the status and fire-related ecology of *Strymon acis bartrami*. Journal of the Lepidopterists' Society 58(4):223-227.
- Salvato, M.H., and H.L. Salvato. 2007. The influence of hurricane and tropical storm activity on resident butterflies in the lower Florida Keys. Journal of the Lepidopterists' Society. 61: 154-164.
- Salvato, M.H., and H.L. Salvato. 2008. Notes on the feeding ecology of *Strymon acis bartrami* and *Anaea troglodyta floridalis*. Florida Scientist. 71: 323-329.
- Salvato, M.H., and H.L. Salvato. 2010. *Misumenops bellulus* (Araneae: Thomisidae) a predator of larval *Anaea troglodyta floridalis* (Nymphalidae). News of the Lepidopterists' Society. 52:6-8, 25
- Salvato, M.H., H.L. Salvato, and M.K. Hennessey. 2009. *Chetogena scutellaris* (Diptera: Tachinidae) and endoparasite of larval *Anaea troglodyta floridalis*. News of the Lepidopterists' Society. 51: 85,101,106.
- Schwartz, A. 1987. The butterflies of the Lower Florida Keys. Milwaukee Public Museum, Contributions in Biology and Geology 73:1-34.
- Schwarz, K.A., R.A. Worth, and T.C. Emmel. 1996. Conservation of two threatened south Florida butterflies and their host plant (Lepidoptera: Lycaenidae, Nymphalidae). Holarctic Lepidoptera 3:59-61.
- Schweitzer, D. 2003. Telephone conversation with Paula Halupa. The Nature Conservancy. New Jersey. Unrecorded date, 2003.
- Slocum, M.G., W.J. Platt, and H.C. Cooley. 2003. Effects of differences in prescribed fire regimes on patchiness and intensity of fires in subtropical savannas of Everglades National Park, Florida. Restoration Ecology 11:91-102.
- Smith, D.S., L.D. Miller, and J.Y. Miller. 1994. The Butterflies of the West Indies and South Florida. Oxford University Press, New York.

- Snyder, J.R., M.S. Ross, S. Koptur, and J.P. Sah. 2005. Developing ecological criteria for prescribed fire in South Florida pine rockland ecosystems. USGS Open File Report OF 2006-1062.
- The Institute for Regional Conservation. 2006. Mapping of the Natural Forest Community System and Endangered Plants of Miami-Dade County, Florida. The Institute for Regional Conservation. Miami, Florida.
- The Nature Conservancy. 2010. Initial estimates of the ecological and economic consequences of sea level rise on the Florida Keys through the Year 2100. The Nature Conservancy, Florida Chapter, Altamonte Springs, Florida.
- Treat, A.E. 1975. Mites of Moths and Butterflies. Cornell University Press, Ithaca, New York.
- U.S. Climate Change Science Program. 2008. Preliminary review of adaptation options for climate-sensitive ecosystems and resources. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Julius, S.H., J.M. West (eds.), J.S. Baron, L.A. Joyce, P. Kareiva, B.D. Keller, M.A. Palmer, C.H. Peterson, and J.M. Scott (Authors)]. U.S. Environmental Protection Agency, Washington, DC.
- U.S. Fish and Wildlife Service. 1999. South Florida multi-species recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia.
- U.S. Fish and Wildlife Service. 2000. Fire management plan, National Key Deer Refuge. U.S. Fish and Wildlife Service, Big Pine Key, Florida.
- Williams, K.L., K.C. Ewel, R.P. Stumpf, F.E. Putz and T.W. Workman. 1999. Sea-level rise and coastal forest retreat on the west coast of Florida. *Ecology* 80:2045–2063.
- Williams, T. 1996. The great butterfly bust. *Audubon* (March-April):30-37.
- Worth, R.A., K.A. Schwarz, and T.C. Emmel. 1996. Notes on the biology of *Strymon acis bartrami* and *Anaea troglodyta floridalis* in south Florida. *Holarctic Lepidoptera* 3(2): 62-65.
- Zhong, H. 2009. Impact of mosquito aerial ULV spray on Miami blue butterflies. Florida Department of Agriculture and Consumer Services Contract Number 010978. Final Report from Florida A & M University, College of Engineering Sciences, Technology and Agriculture, Public Health Entomology Research and Education Center to Florida Department of Agriculture and Consumer Services, Tallahassee, Florida.

APPROVAL/CONCURRENCE: Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes, including elevations or removals from candidate status and listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all resubmitted 12-month petition findings, additions or removal of species from candidate status, and listing priority changes.

Approve:  June 15, 2010
for Regional Director, Fish and Wildlife Service Date

Concur: _____
Director, Fish and Wildlife Service Date

Do not concur: _____
Director, Fish and Wildlife Service Date

Director's Remarks:

Date of annual review: May 25, 2010

Conducted by: Paula Halupa, South Florida Ecological Services Office